regardless of how much more enjoyment computers might add to the learning process, many computer-using teachers were not impressed with the computer's contribution to improving students' academic performance.

Moreover, rather than naming achievement outcomes as things students "learned better, faster, or more thoroughly," some teachers named behavioral or attitudinal outcomes. The ones most frequently named were "following directions" (6%), "social and helping skills" (3%), "motivation" (3%), and "independence and self-esteem" (3%). "Following directions" was named as an outcome more in low-ability elementary and middle-grade classes than elsewhere. "Social and helping skills" were more often mentioned by high school English teachers. And "motivation" was named more often by high school math and science teachers. (Each was named by about 8% to 10% of those types of teachers.)

Summary of Perceived Effects

The opinions of computer-using teachers and principals about changes in computer use and the impact of computers very much echo the more "objective" data about patterns of computer use that we reported in the first two issues of this newsletter. Together, our analyses indicate that schools are becoming serious about trying to use computers to reach important learning objectives. They report substantially greater use (e.g, more competition for computer time, fewer days idle, more teacher borrowing); more activity directed to accomplish an academic goal (e.g., less game playing); increased interest in having students using computers as a tool for improving their intellectual productivity (e.g., increased word processing use); some restructuring of arrangements for supervising students (e.g., greater use of laboratory and library settings for learning); increased cooperation among teachers and a greater investment in teacher preparation time (particularly for high-ability classes and in high school).

The most pervasive perception among teachers is that computers have improved the climate for learning by increasing student motivation in subjects for which they use computers. They are less willing to cite actual improvement in student learning generally, but they see several specific areas of improvement -- students helping one another, particularly in high-ability classes using discovery learning and problem-solving software and in high school classes involving writing; students working independently without close adult supervision; below-average and learning-disabled students improving their computational skills in mathematics by means of computer-assisted instruction; and high-ability students exercising their reasoning and thinking skills. They see the computer as having brought benefits primarily to high-ability students at all levels and to low-ability elementary and middle-grade students, although the benefits seen are primarily described as "opportunities to learn" rather than concrete achievements. Learning outcomes are viewed most positively in schools emphasizing word-processing activities, and nearly all outcomes are significantly stronger in schools with better computer-to-student ratios.

Evidence of Effectiveness

How accurate are those perceptions? Have instructional programs using computers accomplished as much as participating teachers and principals believe -- or have they helped even more than the participants recognize? As social scientists, we understand that participants in a social system do not always have the distance and breadth of experience required to know the consequences of their activities. The perspectives of school-based educators are vitally important to understand the role that computers are playing in school classrooms today. But we need additional evidence.

First, because most methods of instruction teach most students some things, we should consciously use the word "effective" to mean learning in comparison to other methods or programs of instruction. Thus, we should ask whether using computers in a particular setting enables those students to learn better and learn faster and to learn with less cost in personnel, materials, and equipment than if the same instruction were provided in other ways. Also, we must consider that teaching students certain skills by computer may take time away from their learning other skills. Thus, an appropriate evaluation of computer-based instruction must take into account the value of the skills or content learned by computer in comparison to

the "opportunity cost" of skills and content not learned.

We need to develop or use appropriate tests that measure how well students have mastered the learning objectives that we set out for them -- or other capacities that may have developed serendipitously in the process of using computer programs. These tests might be standardized achievement tests if the instructional objectives match fairly well the content of such tests. But in many cases, we must develop tests from scratch, based on concrete curriculum objectives covering a variety of factual, integrative, and analytic learning. We should measure the appropriate skills both before and after the learning experience so that we can identify learning actually due to the experience itself rather than learning that was previously acquired.

We cannot depend only upon the judgments of observers or participants to know the relative effectiveness of computers compared to alternative methods, especially for diverse populations of students with varying academic backgrounds, learning styles, and abilities. One program of instruction may produce some outstanding accomplishments by some students, and it may be regarded as evidence of the value of that approach. Had another instructional approach been used, a different pattern of accomplishments, perhaps equally valuable, may have resulted. Without comparing across instructional methods and considering the achievements of ALL students in a class, we are at best gaining only partial knowledge of the impact of an instructional approach.

Thus, we need to measure student accomplishments not only among students using computers, but also among students receiving alternative methods of instruction with the same educational objectives. To be most helpful, the evaluation should be conducted in settings employing planned experimental designs so that biases associated with self-selection do not artificially color our conclusions. For example, if the more instructionally effective teachers choose to use computer-based instructional programs, greater student achievement in those classes may be teacher effects, not the effects of the computer-based instruction.

We need to take these measurements under varying conditions in order to learn the limits within which our conclusions about instructional effectiveness hold. Do they hold only for classes of high-ability students or for classes of low-ability students? Do they appear only when heterogeneous classes are taught using certain methods adapted to the varying needs of their students? Do they hold only when the student-to-computer ratio within a classroom is at least 2-1, or 4-1, or 8-1? Do they hold only for classes of teachers of exceptional ability or only for teachers enthusiastic about using computers, or do computer-based methods mainly improve the teaching effectiveness of teachers who are "just adequate"?

Needed Research

The results reported here -- outcomes of using computers perceived by teachers and principals -- are essentially hypotheses about the conditions under which various aspects of effectiveness hold. They await empirical verification using well-designed field studies and appropriate measures of student accomplishment.

It is time for school systems that have used computers for several years to organize or participate in well-designed evaluations to measure the relative effectiveness of computer-based approaches to instruction. Such evaluations should employ experimental designs -- that is, both "computer" and "non-computer" approaches to teaching the same material, random assignment of students or classes to these alternative treatments, and post-tests equally appropriate to the instruction given by each method. Many schools now have enough experience in using computers for certain subjects and grade levels to be excellent sites for such studies.

In the next several years, we plan to bring together schools and school districts willing to conduct such evaluations into a cooperative research activity -- the **National Field Studies of the Effectiveness of Instructional Uses of School Computers**. Our work will focus on five distinct subject-areas at the upper-elementary and middle-school levels: computer-assisted instruction in mathematics, writing, earth science, reasoning and problem-solving skills, and social studies. Schools and districts interested in participating in these studies are welcome to write to us for further information.

Newsletter Issues 4 - 6

Because of the importance of computers in mathematics and science education, we decided to devote an entire issue to that topic, thus postponing it until the next issue (Issue 4). Subsequently, issue 5 will focus on computer programming and computer literacy, and issue 6 will discuss writing, language arts, social studies, and vocational applications. Roughly, two months of work go into the preparation of each issue, so expect the series to conclude about April.

Subscription Information

The complete series of six newsletters is available by subscription for $7.50, payable to The Johns Hopkins University. Write to Computer Survey Newsletters, Center for Social Organization of Schools, Johns Hopkins University, 3505 N. Charles St., Baltimore, MD 21218.

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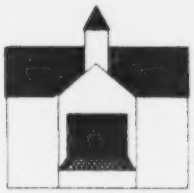
Instructional Uses of School Computers



Reports from the 1985 National Survey Issue No. 4, June 1987

Center for Social Organization of Schools The Johns Hopkins University

Henry Jay Becker, Project Director

In previous issues of this newsletter, we presented basic information about the ways schools use computers, the opportunities different types of students have to use them, and the consequences teachers and principals see from their use. In this and the next two issues, we will present more detailed data about how computers are used in specific areas of the school curriculum. In this issue we focus on traditional topics in science and mathematics education including arithmetic, algebra, geometry, higher math, biology, physics, chemistry, and general science. In the next issue, we will include coverage of less traditional mathematics areas including logic, Logo, and general problem-solving and discuss "computer literacy" and computer programming instruction.

Apart from Arithmetic Drills, Very Little School Computer Use is For Mathematics and Science Instruction

From the earliest attempts to use electronic computers for school-based instruction to the present, arithmetic drills and limited tutorial instruction in arithmetic have been among the most common computer activities in schools. Despite the concentration of mathematics applications in the early grades, in the secondary grades only a very small portion of instructional activity with school computers has been devoted to traditional mathematics subject-matter. Science subject-matter has constituted a similarly small part of school computer use, at both elementary and secondary levels. These conclusions may startle some readers because of the commonly held association between computers and mathematical and scientific pursuits. But these conclusions become inescapable from examining the facts about computer use in schools shown in Table 1.

Table 1 shows the distribution of instructional computer time in U.S. schools in Spring, 1985 at five grade-level ranges: K-2, 3-5, 6-8, 9-10, and 11-12. Percentages of total computer use at those levels are shown for groups of mathematics subjects, for science, for related "computer" subjects, and for all other subjects. By "subject" we mean the instructional topic or manifest content of the computer programs used by the students. So, for example, programming in a mathematics class was classified as programming use if the instructional topic reported for the activity was described in terms of computer programming competencies; it was classified as mathematics if the topic reported was a mathematics skill. Participating teachers reported on one sample instance of computer use in one class or subject. Each report was weighted by the frequency that computers were used in that class or subject and by the number of classes or subjects for which the teacher used computers. (The results in Table 1 differ somewhat from similar data presented in Issue 2 of this newsletter because of refinements in these measures.)

The proportion of computer time devoted to mathematics instruction is shown in the top part of Table 1. For example, 38% of the computer time used by kindergarten through second-grade students was spent on arithmetic-related activities. In contrast, algebra and geometry -- typically taught to 9th and 10th grade students -- occupied only 2% of the computer time in all

ninth- and tenth-grade computer-using classes. Moreover, through the 10th grade, there was vastly more use of computers for basic mathematics (remedial instruction, applications of basic computations in "word problems," etc.) than in the more advanced mathematics topics. Use for understanding and practice in algebra, geometry, trigonometry, and advanced mathematics altogether constituted roughly 3% of the computer time at both the middle school and high school levels while general math instruction occupied 24% of middle school computer use and roughly 7% of high school use (13% in grades 9-10 and 3% in grades 11-12).

Looking at the mathematics data in Table 1 from another perspective, more than one-quarter of all mathematics taught by means of computers was taught to children in the 2nd grade and below, and 63% of the use of computers for mathematics occurred in grades 5 and below. Only 8% of the use of computers for strictly mathematics topics (from remedial arithmetic through calculus and statistics) occurred in the high school grades.

In science classes, computer use occupied about 5% of the instructional time on computers in high school, roughly 3% in the middle grades, and only 1% in the elementary grades. At no grade level did science instruction using computers comprise as much as 10% of that grade's overall use of computers. The proportion of computer use going to science instruction was at its maximum in grades 9 to 10 and fell off sharply (to 3 or 4%) in the grades immediately above and below that range.

Yet Many Math and Science Teachers Use Computers for Instruction

This is not to say that few science and mathematics teachers were using or teaching with school computers. In middle and secondary schools, about 20,000 teachers of science courses and 56,000 teachers of math courses made some use of computers in those subjects during the 1984-85 school year. These teachers constitute roughly one-sixth of the science teachers and one-third of the math teachers in the middle and high schoools.

Table 1: Proportion of Instructional Computer Use(1) for Mathematics, Science, and Computer Subjects by Grade Level, Spring, 1985.

INSTRUCTIONAL FOCUS OF USE	GRADE LEVELS OF COMPUTER-USING CLASSES				
	K-2	3-5	6-8	9-10	11-12
Mathematics					
Whole number arithmetic(2)	38%	25%	8%	2%	1%
Intermediate mathematics(2) (decimals, fractions, and percents, and math applications for older students)	0%	12%	16%	11%	2%
Algebra & geometry(4)	0%	0%	2%	2%	1%
Advanced mathematics	0%	0%	1%	1%	1%
Sub-Total: traditional math instruction(3)	(38%)	(37%)	(26%)	(16%)	(5%)
Computer topics (largely related to math)					
Logic, logo, & problem-solving	2%	4%	7%	2%	0%
Computer literacy --unclear topics	8%	11%	7%	5%	5%
Computer programming(4)	3%	2%	19%	24%	51%
Sub-Total: computer topics	(13%)	(17%)	(33%)	(31%)	(51%)
Science (all subjects)	1%	1%	3%	9%	4%
Other subjects (language arts, writing, business, etc.)	48%	45%	38%	44%	35%
Total	100%	100%	100%	100%	100%

(1)Each computer-using class is weighted by the estimated time of total use.

(2)Unspecified mathematics (13% of all use) classed as whole number arithmetic (K-2); 67% arithmetic, 33% fractions, decimals, percents (3-5); 33% arithmetic, 67% fractions (6-8); 50% fractions, etc., 20% arithmetic, and 30% algebra (9-12).

(3)Of all traditional mathematics instruction using computers, 26% occurred at grades K-2; 47% at grades 3-5; 18% at grades 6-8; 5% at grades 9-10; and 3% at grades 11-12.

(4)Programming in a math class was classified as programming use if the topic reported for the activity was a programming topic and as mathematics if the topic reported was a math topic.

How can this be? How can so many secondary school mathematics and science teachers be using computers, but so little of the computer use be in mathematics and science? Three factors are at work here: the courses that mathematics and science teachers teach for which they use computers, the intensity that computers are used in these courses, and the particular instructional activities and focus of computer use in these courses.

Math and Science Teachers Use Computers Primarily to Teach ABOUT Computers

In addition to using computers for instruction in math and science per se, math and science teachers at the secondary level are heavily involved in teaching computer literacy and programming courses. If we consider all high school math and science teachers who used computers for at least one course they taught during 1984-85, and we then select at random one computer-using course for each of these teachers, we would find that about 10% of the science teachers' courses and fully one-half of the math teachers' courses involved using computers to teach programming or computer literacy and not math or science subject-matter.

Moreover, the programming and computer literacy classes tended to use computers more often than these same teachers' mathematics and science courses. So if we took a sample of OCCASIONS on which computers were used in courses taught by math and science teachers, nearly one-fourth of those taught by science teachers and nearly two-thirds of those taught by math teachers would have involved teaching programming or computer literacy. At the middle school level, the proportion of math and science teachers' instructional time on computers going to computer instruction is somewhat smaller but is still substantial (17%, science; 28%, mathematics).

Thus, above the level of arithmetic drills, the primary involvement of math and science teachers with computers (at least as of Spring, 1985) has been to use them as the object of instruction rather than as the means of providing traditional instruction in mathematics and science.

Intensity of Use by Type of Class

Secondary science and mathematics classes that used computers did not use them even as frequently as did computer-using classes in other traditional subjects -- in particular, business education, writing, basic mathematics and language arts. Figure 1 shows the proportion of different kinds of classes that (1) used computers in the 3 days prior to the survey, (2) used computers "every week" or "most weeks", and (3) used computers for at least 3 days out of every 10 during the year. Results are shown for math classes, science classes (except for the elementary level, where there were too few), computer classes, and other classes, with some of the mathematics and science categories divided into more specific subjects. "Classes" at the elementary level refers mainly to "subjects" -- not separate class periods as in secondary school.

In high school, among classes that used computers at all, both science classes and mathematics classes (algebra and above) used computers less intensively than did classes in other subjects. The computer-using teachers that, as a group, used computers LEAST intensively with their students were chemistry teachers, where only one-sixth of the computer-using classes used computers to the extent measured in Figure 1 (using an index that combines the three aspects of use shown in that figure). One-third of the biology classes and 44% of high school physics classes used computers to that extent.

Computer-using classes in algebra, geometry, trigonometry, and other advanced math subjects reported levels of intensity similar to those reported for science classes. For example, only 18% of the computer-using classes in high school mathematics (algebra and up) reported using computers "every week" or "most weeks," compared to nearly two-thirds of the computer-using classes outside of mathematics, science, and computer science.

At the middle school level (grades 6-8), fewer than one-fifth of the computer-using science classes used computers for at least 3 days out of every 10. More than half of middle grade mathematics classes that used computers at all used them that much. In classes outside

of math and science that used computers, nearly three-fourths used computers for 3 days out of 10.

In the elementary grades, the pattern was very different than in the higher grades. Computers in mathematics instruction were used on a more frequent basis than in other academic subjects. For example, two-thirds of the elementary math classes using computers used them "most weeks" or "every week" compared to just over half of the classes using computers for other subjects (other than "computer literacy"). We had only 14 elementary classes in our survey where computers were used for science instruction, and computers were used in these classes only occasionally.

Math and science computer-using teachers used computers relatively intensively in two general areas: (1) for basic and intermediate mathematics (below algebra) and (2) for classes and units in computer programming and computer literacy. At all levels, elementary through high school, teachers who used computers for these topics used them frequently. A majority of computer-using teachers of pre-algebra mathematics classes reported in 1985 that they used computers "every week" or "most weeks" for topics in whole-number arithmetic, fractions, decimals, or percents. These basic mathematics courses reported "intensity percentages" in the 50%-70% range from elementary through high school. In contrast, the more advanced math courses had percentages around 20% for the measures of frequency of use shown in Figure 1.

Not surprisingly, the courses with the highest reported intensity of computer use were computer-specific courses such as programming and computer literacy, taught mainly by math and science teachers. Their reported percentages were around 90% in high schools, 70% to 90% in middle schools, and 55% to 85% in elementary schools.

How Computers Were Used in Computer-Using Math and Science Classes

A third part of the explanation for the contrast between the large number of computer-using math and science teachers and the small proportion of computer time being devoted to science topics and mathematics topics (above arithmetic) has to do with the instructional activities occurring in computer-using math and science classes. A substantial fraction of both "math" and "science" computer activity in the middle grades is instruction where the computer skills are themselves the objective of instruction rather than the means of instruction (i.e., "computer literacy" as a math or science subject).

For example -- see Table 2 -- nearly one-fourth of all activity in computer-using science classes in secondary school is programming. So is 15% of the computer activity in middle school mathematics courses and 17% of the computer activity in high school math classes (algebra and up). Of course, not all programming instruction is for the purpose of

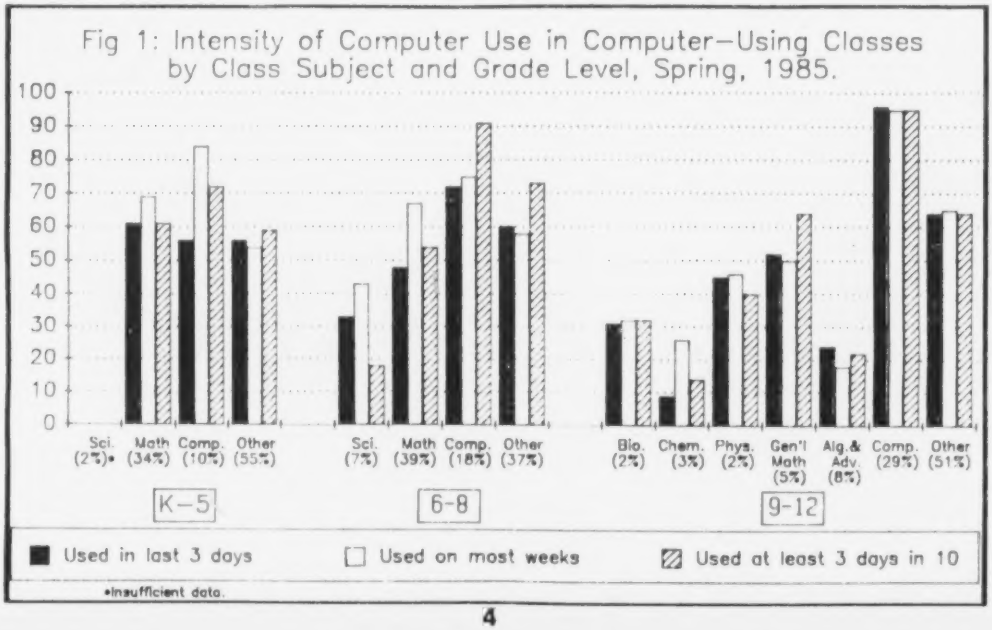


Table 2: Type of Computer Activities in Math, Science, and Computer Classes by Subject and Grade Level, Spring, 1985.

SUBJECTS BY GRADE LEVELS	TYPE OF ACTIVITY				
	Drills	Tutorials	Programming	Writing Text	Other Uses With 10 or More Percent
Elementary (K-5)					
Science class*					
Math class	72%	14%	8%	3%	
Computer class	11%	8%	24%	17%	28% (graphics, printing)
Other classes	69%	16%	4%	8%	
All K-5 computer using classes	62%	15%	8%	8%	
Middle (6-8)					
Science	25%	13%	22%	10%	27% (Simulations)
Math	58%	15%	15%	4%	
Computer class	14%	16%	54%	12%	
Other Subjects	47%	25%	6%	16%	
All 6-8 Subjects	40%	20%	23%	12%	
High School (9-12)					
Biology	85%	8%	0%	0%	
Chemistry	40%	31%	0%	1%	13% (Data applications) 14% (Simulations)
Physics	33%	16%	18%	2%	18% (Data applications)
All Science classes**	42%	13%	25%	3%	
Math: below algebra	68%	24%	0%	1%	
Math: algebra or more advanced	43%	14%	21%	0%	12% (graphing tool)
Computer class	7%	3%	75%	13%	
Other Subjects	31%	16%	9%	30%	
All 9-12 Subjects	22%	10%	40%	19%	

* Insufficient data.

** Includes earth science and general science also.

teaching programming skills. Programming can be used to improve mathematics or science comprehension as well. Particularly in classes like algebra, some of the programming activity focuses on programming objectives, some on mathematics objectives, and some on both. Nevertheless, between the programming occurring in explicitly organized computer literacy and computer programming classes and the programming within advanced mathematics and science courses, programming and not traditional math and science topics got the overwhelming emphasis among high school computer-using math and science teachers.

Table 2 also provides information about the dominance of drill-and-practice programs in basic and intermediate mathematics instruction using computers. More sophisticated tutorial (explanatory) and problem-solving programs and the more organizationally complex uses such as simulations, laboratory data collection, statistical graphing, and data retrieval programs were less frequent activities than were drills for mathematics at all grade levels. Math drills formed nearly three-fourths of the mathematics computer activity at the elementary grades and two-thirds of the remedial and general math use of computers in high school.

In contrast, science instruction using computers -- although limited in time -- was broader in scope. Simulation activities slightly outnumbered drill uses at the middle school level. In high school physics, drills occupied more time than any other single activity, but as a group, data-based applications, tutorials, programming, and use of word-processors comprised fully two-thirds of the computer activity for those courses. Chemistry courses involved substantial use of simulations, data bases, and tutorials. Among the high school science courses, drill activities were dominant only in biology -- where drills were about the only computer activity in use.

How Computers Were Used in Math and Science Instruction

Tables 3 through 6 provide a glimpse at how computer-using teachers used computers for mathematics and science instruction at different grade levels and with different types of classes. The information comes from survey questions about "the most recent occasion" on which the teacher used computers with a particular class.

Table 3: Characteristics of Most Recent Occasion of Computer Use, Elementary Mathematics Classes, For All Classes and Low Ability Classes, and by Teacher's Computer Expertise, Spring, 1985.

Characteristics of Most Recent Occasion of Use	All Classes	Low-Ability Classes	By Teacher Computer Expertise		
			Low	Medium	High
Percent of classes using computers					
in the classroom	77%	62%	81%	72%	81%
in a lab or elsewhere and teachers went to lab	15%	31%	15%	14%	13%
in a lab or elsewhere and teachers stayed in class	8%	7%	4%	14%	8%
Number of computers in room					
mean (median in parentheses)	3 (1)	4	3	3	4
Number of students present					
mean (median in parentheses)	20 (22)	11	19	20	19
Ratio of computers to students					
mean	1:15	1:5	1:15	1:15	1:13
median					
Percent of classes where ALL students in the class used computers that day	40%	32%	40%	38%	45%
Percent of classes in which ALL computer-using students did same assignment	48%	58%	55%	41%	35%
Percent where students did computer work					
Alone (with no help)	36%	51%	39%	19%	52%
Individually (with help or observation)	14%	16%	16%	14%	6%
In pairs	45%	29%	41%	54%	42%
In groups of more than two	6%	3%	4%	14%	0%
Mean number of minutes per student turn	17	22	16	18	20
Student activities on this occasion (adds to more than 100% -- multiple responses:					
Drills	84%	88%	84%	82%	92%
Tutorials	19%	10%	13%	21%	34%
Program writing	7%	2%	0%	15%	14%
Word processing	3%	2%	1%	4%	9%
Other	17%	16%	19%	13%	17%
While NOT using computers, students...					
watched computer users	6%	8%	5%	6%	3%
did individual seatwork	67%	74%	71%	68%	69%
small group work	19%	11%	16%	19%	18%
participated in class discussion	8%	7%	8%	6%	10%
Activity was considered to be...					
enrichment	55%	37%	59%	53%	53%
remediation	30%	57%	26%	37%	21%
regular instruction	15%	6%	16%	10%	27%
Teacher spent most of his/her time					
with students using computers	10%	17%	13%	9%	4%
with students NOT using computers	77%	56%	74%	73%	94%
(remainder said 'equal time with each')					
Some other items (not confined to the most recent occasion of use)					
What to do with students needing help?					
"Give them extra time on computer"	15%	24%	14%	10%	3%
What to do with rapid learners?					
"Give them enrichment on computer"	28%	24%	14%	40%	36%
Percent of classes using computers...					
more than 1 day per week	61%	47%	47%	76%	74%
more then 3 days per week	27%	21%	25%	21%	51%

Table 4: Characteristics of Most Recent Occasion of Computer Use, Middle Grade Mathematics Classes, For All Classes and Low Ability Classes, and by Teacher's Computer Expertise, Spring, 1985.

Characteristics of Most Recent Occasion of Use	All Classes	Low-Ability Classes	By Teacher Computer Expertise		
			Low	Medium	High
Percent of classes using computers					
in the classroom	45%	65%	62%	25%	32%
in a lab or elsewhere and teachers went to lab	47%	29%	24%	70%	64%
in a lab or elsewhere and teachers stayed in classroom	9%	7%	14%	5%	0%
Number of computers in use					
mean (median in parentheses)	5 (4)	4	3	5	9
Number of students present					
mean (median in parentheses)	18 (18)	13	20	16	20
Ratio of computers to students					
mean	1:10	1:7	1:13	1:6	1:8
median	1:4				
Percent of classes where ALL students in the class used computers that day	39%	39%	34%	47%	30%
Percent of classes in whcih ALL computer-using students did same assignment	45%	43%	43%	41%	53%
Percent where students did computer work..					
Alone (with no help)	44%	51%	52%	30%	50%
Individually (with help or observation)	8%	8%	7%	9%	0%
In pairs	40%	36%	35%	50%	38%
In groups of more than 2	8%	5%	6%	11%	13%
Mean number of minutes per student turn	19	20	18	18	24
Student activities on this occasion (adds to more than 100% -- multiple responses)					
Drills	73%	80%	65%	90%	54%
Tutorials	18%	27%	15%	16%	27%
Program writing	10%	3%	8%	8%	21%
Word processing	3%	0%	6%	3%	5%
Other	24%	19%	31%	11%	34%
While NOT using computers, students...					
watched computer users	9%	7%	5%	12%	5%
did individual seatwork	60%	58%	67%	52%	67%
small group work	11%	14%	4%	18%	19%
participated in class discussion	20%	61%	24%	19%	8%
Activity was considered to be...					
enrichment	39%	24%	55%	22%	32%
remediation	44%	57%	28%	69%	34%
regular instruction	17%	19%	17%	9%	35%
Teacher spent most of his/her time					
with students using computers	9%	11%	8%	13%	9%
with students NOT using computers	63%	60%	77%	46%	60%
(remainder said 'equal time with each')					
Some other items (not confined to the most recent occasion of use:					
What to do with students needing help?					
"Give them extra time on computer"	17%	12%	14%	21%	17%
What to do with rapid learners?					
"Give them enrichment on computer"	45%	50%	38%	62%	33%
Percent of classes using computers					
more than 1 day per week	53%	48%	46%	71%	27%
more then 3 days per week	20%	26%	24%	15%	16%

Each response is weighted according to the number of computer-using classes the teacher taught. This accounts for the fact that each teacher could report about only one class on the survey form. So the results picture how computers are used in computer-using math and science CLASSES at different grade levels.

1. Elementary mathematics classes

In three quarters of the elementary school classes in which computers were used for mathematics, students did their computer work in their own classroom rather than in a computer laboratory or other room. (See Table 3 for these and other results reported in this section.) In a majority of cases, only a single computer was available. The typical computer-to-student ratio was 1:13. In only 40% of the classes did all students in the class use computers on the same day, largely because so few computers were present in the room. For all students to have used computers for mathematics on the same day, it would have required computer activity to be spread over at least two hours during the day in most classes because a 1:13 ratio would not have enabled even half of the students to go to computers (in pairs) for, say, a 15 minute turn within the confines of a one-hour period for mathematics.

Computerized drill was by far the most common activity for elementary school mathematics. Programs that explained concepts or procedures (tutorials) were used only one-fifth as often as straight drills. In about half of the classes, the students doing math on the computers used different programs from one another. This was more likely because classes had only a limited number of copies of the same software than because of a planned program of individualized instruction. A majority of teachers regarded the computer work as enrichment (55%) rather than as remediation (30%) or as a regular part of mathematics instruction (15%). Teachers were twice as likely to suggest computer enrichment activities for students who finished their other work early as they were to suggest computer remediation activities for students who had trouble keeping up with the class (28% vs 15%).

Students worked in pairs almost as often as they worked individually (45% vs. 50%). In only one-third of the classes was computer use a totally solo activity -- individuals working without others helping or watching. The typical turn at the computer lasted 15 minutes. During the time that some students used computers, the remaining students were doing seatwork exercises in two-thirds of the classes. Whole-class activity was very infrequent during periods of computer use (8%). Teachers spent most of their time helping the students with their seatwork or other non-computer activities (77%) rather than watching over the students at the computers (10%).

Teachers were classified according to their computer expertise and experience (using self-report indicators of extent of computer experience, general educational level, extent of computer training, self-assessments of computer knowledge, reports of breadth of computer experiences, use of computers for professional functions, and extent of use of a computer at home). The teachers were classified into "low," "medium," and "high" groups according to arbitrary dividing points, with the "high" group encompassing 17% of the elementary computer-using math teachers and the "medium" classification applying to another 22%.

Among the teachers who used computers for math instruction in elementary schools, high-expertise and medium-expertise teachers used computers much more frequently than low-expertise teachers. They taught students of somewhat higher ability, but in many ways their pattern of use was similar to the way more typical "low-expertise" elementary math teachers used computers. They used drill-and-practice programs at least as frequently, but they also mixed in tutorials, programming, and word-processing more often than those computer-using elementary math teachers who were less "expert". As with the less expert teachers, only a minority of the more expert teachers were able to give ALL students in the class computer time on any one day. They gave students somewhat longer turns (20 minutes vs. 15 minutes). But seatwork dominated the time of students waiting for their chance to use computers as much as in other classes.

Computers were still seen primarily as an enrichment experience even by medium- and high-expertise teachers, but a higher proportion of the most expert teachers did report using computers as a regular part of math instruction (28%). Also, the teachers with the most

computer expertise individualized student computer assignments more than did others, and they had students work alone at computers more than other teachers did. Nearly all of the high-expertise teachers spent most of their own time with students who were NOT using the computers, having trained students to use the equipment without need of their own help.

Besides reporting data for all mathematics subject-matter instruction in classes for grades K to 5, Table 3 also provides data separately for classes for "low-" and "very-low" ability students. This group constituted 20% of all of the classes reported in the overall results. These lower-ability classes differed in their computer use from other elementary math classes in some ways. A higher proportion of their use went for remediation (57% vs. 30% for all elementary math classes). A higher proportion of their use was in computer labs as opposed to classrooms. They generally had a much better ratio of students-to-computers than in other math classes. Their teachers used a somewhat narrower range of software (i.e., a larger fraction of use was drill-and-practice rather than tutorials and programming activities). And they had less differentiated computer assignments (i.e., typically everyone used the same programs rather than different programs for different students).

2. Middle grade (6 to 8) mathematics classes

Compared to elementary math classes, math classes in grades six to eight that used computers used them much more often in computer laboratories and used them more for remediation and less for enrichment (Table 4). About as many middle grade math teachers (45%) saw computers as a way of keeping students occupied after they completed their other work as reported using computers for remediation (44%).

Middle grade math teachers used computers somewhat differently according to their own computer expertise. Medium- and high-expertise teachers overwhelmingly used computer in labs, but low-expertise teachers used them primarily in classrooms. And therefore, higher expertise teachers had more computers available and a better student-to-computer ratio. It is the medium-expertise teachers who used the computers most, however, not those with the highest computer expertise. And the medium-expertise teachers used computers more often for remediation and for providing activities to students who finished their other work than did other middle grade math teachers. They are also the ones who most often had students do their computer work cooperatively. The high-expertise math teachers at this level are distinguishable instead by their greater use of computers as a regular part of class instruction (rather than for enrichment or remediation) and by their greater diversity of software use (i.e., less reliance on drill-and-practice). But they were not as frequent computer users and two-thirds of them reported that non-users were engaged in seatwork, a higher fraction even than less computer-expert middle grade math teachers.

Among middle grade computer-using math classes, the 31% of classes involving lower-than-average ability students did not differ substantially from the remaining classes except for a somewhat greater emphasis on remediation. But the types of computer programs used, the way that students used computers, and what students did away from the computer in these low-ability classes were all roughly similar to how other middle grade math classes used computers.

3. High school mathematics classes

In high school mathematics instruction, computers were used very differently depending on the level of mathematics being taught (Table 5). General math classes used computers primarily for remedial purposes and emphasized drill-and-practice, and, to a lesser extent, tutorial programs. On the most recent occasion that computers were used in the class, students worked alone about half the time, just as in middle grade math classes, and, more often than not, different students used different software and some students didn't use computers at all. (Table 5 does not separate high school general math classes by teacher computer expertise because there were too few teachers in each category to present reliable data.)

In high school algebra and higher mathematics courses, activity patterns involving computers were quite different than those described for elementary, middle, and high school general math classes. Use of computers in higher math classes was much less frequent -- even if we restrict consideration to only those algebra and higher math classes that made some use of computers (as in Table 5). Only 13% of

Table 5: Characteristics of Most Recent Occasion of Computer Use, High School Mathematics Classes, For General Math Classes and Algebra/Higher Math Classes, the Latter by Teacher Expertise, Spring, 1985.

Characteristics of Most Recent Occasion of Use	General Math Classes	Algebra, Geometry, Trig, Advanced Math All Classes	By Teacher Computer Expertise Low	Med/High
Percent of classes using computers				
in the classroom	80%	59%	49%	69%
in a lab or elsewhere and teachers went to lab	17%	40%	47%	31%
in a lab or elsewhere and teachers stayed in classroom	4%	2%	4%	0%
Number of computers in use				
mean (median in parentheses)	8 (4)	8 (5)	9	7
Number of students present				
mean (median in parentheses)	17(20)	18 (20)	17	19
Ratio of computers to students				
mean	1:7	1:6	1:5	1:7
median	1:3	1:3		
Percent of classes where ALL students in the class used computers that day	32%	59%	53%	65%
Percent of classes in whcih ALL computer-using students did same assignment	44%	78%	76%	85%
Percent where students did computer work..				
Alone (with no help)	48%	19%	34%	8%
Individually (with help or observation)	18%	21%	11%	33%
In pairs	26%	45%	43%	36%
In groups of more than	8%	15%	12%	23%
Mean number of minutes per student turn	21	27	32	24
Student activities on this occasion (adds to more than 100% -- multiple responses)				
Drills	86%	42%	44%	37%
Tutorials	34%	23%	26%	26%
Program writing	0%	26%	29%	17%
Word processing	1%	4%	1%	8%
Other	13%	33%	19%	54%
While NOT using computers, students...				
watched computer users	4%	24%	18%	30%
did individual seatwork	84%	49%	40%	53%
small group work	2%	13%	26%	3%
participated in class discussion	10%	13%	16%	14%
Activity was considered to be...				
enrichment	29%	53%	60%	51%
remediation	57%	11%	19%	4%
regular instruction	14%	35%	22%	45%
Teacher spent most of his/her time				
with students using computers	23%	47%	28%	70%
with students NOT using computers	62%	31%	45%	25%
(remainder said 'equal time with each')				
Some other items (not confined to the most recent occasion of use:				
What to do with students needing help?				
"Give them extra time on computer"	11%	13%	15%	4%
What to do with rapid learners?				
"Give them enrichment on computer"	20%	21%	18%	27%
Percent of classes using computers				
more than 1 day per week	63%	13%	17%	9%
more then 3 days per week	37%	8%	15%	0%

Table 6: Characteristics of Most Recent Occasion of Computer Use, Middle and High School Science, Classes -- Middle Grade Classes by Teacher's Computer Expertise; High School Classes by Subject, Spring, 1985.

Characteristics of Most Recent Occasion of Use	Middle Grade Science Classes By Teacher Computer Expertise All	Low	Med/High	High School Science Classes Biology	Chemistry	Physics
Percent of classes using computers						
in the classroom	77%	73%	84%	86%	77%	58%
in a lab or elsewhere and teachers went to lab	17%	18%	13%	13%	12%	41%
in a lab or elsewhere and teachers stayed in classroom	6%	9%	3%	1%	11%	1%
Number of computers in use						
mean (median in parentheses)	4 (2)	4	4	3 (1)	4 (2)	4 (1)
Number of students present						
mean (median in parentheses)	23 (25)	23	24	22(20)	20(22)	15(18)
Ratio of computers to students						
mean	1:15	1:15	1:16	1:17	1:11	1:10
median	1:12			1:20	1:8	1:10
Percent of classes where ALL students in the class used computers that day	56%	41%	58%	27%	44%	50%
Percent of classes in whcih ALL computer-using students did same assignment	81%	88%	68%	97%	77%	96%
Percent where students did computer work..						
Alone (with no help)	21%	28%	20%	13%	4%	26%
Individually (with help or observation)	20%	32%	13%	31%	50%	13%
In pairs	29%	21%	23%	49%	40%	27%
In groups of more than	30%	19%	43%	7%	6%	35%
Mean number of minutes per student turn	20	17	21	21	24	23
Student activities on this occasion (adds to more than 100% -- multiple responses)						
Drills	54%	61%	50%	70%	50%	62%
Tutorials	19%	17%	23%	36%	26%	45%
Program writing	20%	21%	13%	1%	0%	15%
Word processing	6%	2%	10%	4%	1%	2%
Other	16%	8%	24%	23%	27%	43%
While NOT using computers, students...						
watched computer users	26%	*	*	*	14%	*
did individual seatwork	53%				36%	
small group work	6%				34%	
participated in class discussion	15%				16%	
Activity was considered to be...						
enrichment	72%	81%	72%	49%	38%	22%
remediation	4%	8%	1%	37%	27%	1%
regular instruction	24%	11%	27%	14%	35%	76%
Teacher spent most of his/her time						
with students using computers	22%	34%	14%	2%	3%	34%
with students NOT using computers	31%	42%	27%	57%	82%	25%
(remainder said 'equal time with each')						
Some other items (not confined to the most recent occasion of use:						
What to do with students needing help?						
"Give them extra time on computer"	19%	17%	21%	35%	9%	5%
What to do with rapid learners?						
"Give them enrichment on computer"	32%	17%	49%	11%	25%	17%
Percent of classes using computers						
more than 1 day per week	15%	7%	23%	*	14%	40%
more then 3 days per week	8%	3%	14%		10%	13%

* Under 30 teachers

the computer-using higher-level math classes reported using computers more than once per week compared to 63% of the computer-using high school general math classes and a majority of lower grade math classes.

But when algebra and other higher math classes did use computers, it was much more likely to be a major class activity. Compared to general math classes and to math classes at the lower grade levels, more often ALL students in a computer-using algebra class used computers during the same period (59% vs. 32% for high school general math classes); more often they did the same assignment on the computer (78% vs. 44%); the assignments were much more variable with drills being used on only 42% of the occasions (compared to 86% for general math classes); teachers were more personally involved with the computer activities rather than using that time to work with the rest of the class, and computer activities were primarily social interactions rather than solitary ones. In 60% of the higher math classes, students worked in pairs or groups even though the number of students per computer was generally better than in other math classes using computers. And in about one-half of the classes, students who were waiting their turn to use computers were observing the computer-users, doing small group activity, or participating in class discussions -- not doing seatwork, the waiting time activity that overwhelmingly dominated high school general math classes with computers (where 84% said this was the major waiting time activity). Interestingly, the higher level math classes did their computer work in labs much more often than did the general math classes, and yet clearly the computer activity, when it was used, was a much more integrated and important part of their course curriculum, a characteristic often associated in people's minds with classroom rather than laboratory location of use.

The most computer-knowledgeable higher math teachers (medium- and high-expertise teachers) were most oriented to having students use computers in cooperative ways. In only 8% of their classes did students work on computers by themselves. Those teachers spent more time with students who were using computers, as opposed to working with the students who were not using them. And they were much more likely to see computers as a regular part of the presentation of instructional material in their class, as opposed to enrichment or remediation activity. Interestingly, such medium- and high-expert teachers also used computers LESS intensively than did the others using computers for the same subject. Only 9% reported using computers more than once per week. Overall, the major differences between algebra/higher math classes and general math classes in their use of computers were even more pronounced among high school math teachers who were most knowledgeable about computers.

4. Middle grade science classes

Table 6 shows that science classes in the middle grades (and in the high school grades) overwhelmingly used computers in their own classroom rather than in a separate computer lab (77% vs. 23%). Typically, there were only 2 computers present, half as many as for middle grade computer-using math classes (where laboratory use was more common). The typical ratio of computers-to-students approximated that in elementary math classes (1:12). But computers were used very differently in middle grade science classes than in elementary math classes. In the first place, paired and grouped use was common. In 30% of the science classes at that level, students used computers in groups of three or more. Students worked alone without help in only one-fifth of the science classes (half as often as in general math classes). Students in the same class nearly always did the same assignment, very much like in the high school algebra/higher math classes. And seatwork was the major "off-line" activity in only one-half of the science classes -- again like the high school advanced math classes.

Middle grade science teachers split their time almost equally between observing students using computers and working with students who were not then using them (as opposed to the general math teachers who worked primarily away from computers and the higher math teachers who worked more with the computer users). But three-quarters of the computer-using middle grade science teachers saw computer use as being primarily an enrichment activity rather than a regular part of science instruction. Computers were used in 85% of these classes no more than one day per week. That, combined with the poor student-computer ratios, may have limited how well the teachers could integrate computer activities with their curriculum. The more computer-expert science teachers in the middle grades used computers more often with

their classes than those less expert about computers (the opposite pattern from the high school higher math teachers). Also, they emphasized students working at computers in groups more than any of the other teachers in the study. But they too saw computers primarily as enrichment aids rather than as a major means of developing knowledge of scientific facts or methods in their students.

5. High school science classes: biology, chemistry, physics

Like their middle school colleagues, high school science teachers used computers primarily in classrooms and therefore typically had few computers with which to work (Table 6). Overwhelmingly, they had all students do the same task on the computer, but typically not every student used computers on the same day. They used a broad range of computer activities, including a higher proportion of tutorial programs (compared to simple drill-and-practice) than math teachers or middle-grade teachers used.

These generalizations apply very similarly to biology, chemistry and physics classes, but in many other ways the three high school science subjects differed from one another substantially in how computers were used. Biology classes most resembled lower grade and math class use: 70% of the classes did drills on the most recent occasion that computers were used; in only 27% did all students use computers on that day; teachers much more often spent their time with the students who were away from the computers rather than with those using computers; enrichment was the primary function of computer use (only 14% said computers were a regular part of classroom instruction); and remediation was very important as well (35% said they'd give extra computer time to students who needed more help -- more than any other type of math or science teacher).

Students used computers cooperatively in high school science classes rather than individually, but paired use predominated in biology and chemistry classes while physics classes assigned computer tasks to groups of three or more students much more frequently and physics classes also had students work individually more often than in the other subjects.

Physics classes used computers more than did the others. Forty percent were reported to use computers more than once per week compared to 14% for chemistry classes. (These figures include only those science classes that used computers at least some times.) More significantly, in 76% of the physics classes computers were said to be a regular part of providing instruction rather than for enrichment or remediation, fully twice the proportion of high school algebra/higher math teachers giving this answer. Physics teachers spent at least as much time with students using computers as with students who were away from the computers.

Summary

Overall, computers clearly still play a small role in secondary school science instruction, except, perhaps, in high school physics. In 1985, relatively few computer-using science teachers reported using as many as 6 different computer programs with their students in any of their science classes (11% at the middle school level and 32% of the high school computer-users). Some science teachers were using simulations, lab interfacing programs, mathematics calculators, programs that compiled statistics or drew graphs, and other similar data-specific applications, and there was a relatively high degree of satisfaction with some of these categories of programs among those who used them. But very few computer-using science teachers were using these or any other type of instructional software very intensively. As of 1985, there is only the hint that secondary school science instruction might be profoundly affected by computers. The impact is largely still in the future.

In mathematics, computers in 1985 were playing both more and less of a role than they were in science. As a medium through which students at all grade levels can practice basic skills in arithmetic, computers were being widely used from the lowest to the highest grade levels. However the impact on any individual student is difficult to see because very few students using computers in these ways were getting a substantial amount of computer time (e.g., 30 hours during the school year). For higher levels of school mathematics, from algebra on up, the evidence suggests that the

involvement of computers in traditional instructional topics was yet very small.

Apart from basic arithmetic computation, computers have had a major impact on pre-college mathematics in two ways: as a stimulus for providing a new emphasis on logic, problem-solving, and applications of mathematics; and as an object of instruction itself -- the focus on computer literacy and computer programming. These changes in the content of mathematics education can be observed at all levels from elementary to high school. In the elementary grades, the changes show up as activities for keyboard familiarization, in the use of instructional computer programs as "exemplars" of computer-based intellectual activity, in rudimentary programming instruction in both "Logo" and "BASIC," and in occasional use of word-processing programs. In high school, the evidence is strong that semester-long courses in computer programming, and sometimes a whole computer science curriculum, has taken its place as a regular feature of the high school academic curriculum. At the middle grades, a wide range of activities that make use of computers from relatively simple programming to the use of logic and strategy games has been offered to an even broader clientele than the high school computer programming courses. The next newsletter issue will provide detailed data about how computers are being used in these areas.

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